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GIS-Based Spatio-Temporal Analysis of Recorded Tuberculosis Cases and Priority Areas in Nabire Regency

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ABSTRACT

Tuberculosis remains a major public health concern that requires area-based monitoring. At the local level, tuberculosis data are commonly available in tabular form, which limits their ability to reveal spatial variation, temporal change, and priority areas for program monitoring. This study aims to analyze the spatio-temporal pattern of recorded tuberculosis cases in Nabire Regency from 2023 to 2025 using a Geographic Information System. A descriptive quantitative approach was applied, with districts as the units of analysis. Recorded tuberculosis case data were obtained from the Nabire Health Office as published in *Nabire Regency in Figures* 2024, 2025, and 2026. Population data were used as the denominator to calculate case rates per 100,000 population. The analysis included data cleaning, district name standardization, rate calculation, attribute-spatial integration, choropleth mapping, inter-annual change analysis, and priority area classification. The results show that recorded tuberculosis cases increased from 2,142 cases in 2023 to 3,084 cases in 2024, before declining to 2,371 cases in 2025. Nabire District consistently recorded the highest absolute number of cases, while Nabire Barat and Wanggar also showed high relative burdens based on rates per 100,000 population. The main priority areas were Nabire, Nabire Barat, and Wanggar. Uwapa and Teluk Kimi were classified as strengthening-priority areas because of fluctuating patterns and renewed increases in 2025. This study demonstrates that Geographic Information Systems can transform routine health records into operational spatio-temporal information to support area-based tuberculosis program monitoring.

INTRODUCTION

Tuberculosis (TB) remains a major infectious disease that requires sustained attention because it is closely related to transmission, treatment continuity, access to health services, and the quality of case recording. Globally, TB continues to be a major public health concern that requires strengthened surveillance, case detection, and treatment completion (Organization, 2025). In Indonesia, TB remains a national health priority; therefore, district-level case data should be managed not only as tabular reports but also as spatial information that can support program monitoring and policy planning (Indonesia, 2025).

At the local government level, TB data are commonly presented as summaries by administrative area. Although this form of presentation is useful for routine reporting, it is insufficient to reveal spatial variation between districts, changes across years, and areas requiring greater program attention. Recorded TB cases may differ across districts because of variations in population size, access to health facilities, case-finding intensity, reporting quality, diagnostic capacity, and population mobility. Consequently, absolute case counts should be analyzed together with population data to provide a more proportional comparison among districts.

Nabire Regency has diverse geographical and administrative characteristics, including urban, coastal, and relatively remote districts with different levels of access to the regency center and health services. These conditions make an area-based approach relevant for understanding the distribution of recorded TB cases. Analysis at the regency level alone may conceal districts with a relatively high burden because aggregate totals are strongly influenced by densely populated areas. The calculation of TB case rates per 100,000 population is therefore necessary to identify relative differences among districts.

A Geographic Information System (GIS) can integrate health attribute data with administrative spatial data. In Informatics, GIS is not merely a tool for producing maps, but also a computational approach for data cleaning, attribute-spatial integration, indicator calculation, spatial visualization, and location-based decision support. Previous studies have demonstrated that GIS-based disease mapping and spatio-temporal analysis can reveal geographic inequalities in TB burden and support the identification of priority intervention areas (Orozco-Acosta et al., 2023), (Shartova et al., 2023), (Im & Kim, 2021), (Gwitira et al., 2021), (Mohidem et al., 2021).

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Spatial TB studies have been conducted in several countries and regions of Indonesia using approaches such as choropleth mapping, spatial autocorrelation, hotspot analysis, and risk-factor modeling (Madao et al., 2024), (Olivionita et al., 2024), (Diba et al., 2024), (Riznawati et al., 2024), (Inggarputri et al., 2023), (Srisantyorini et al., 2022), (Ramadhani et al., 2021), (Zainuddin et al., 2022), (Fahdhienie et al., 2024), (Dwinata et al., 2025), (Sidiq et al., 2025), (Nahak et al., 2024), (Hasriyati et al., 2026). These studies generally show that TB cases are not evenly distributed but tend to be concentrated in particular administrative areas. However, many previous studies have focused on a single observation year, explanatory risk factors, or statistically defined clusters. Limited research has transformed routinely published district-level TB data into multi-year operational priority information, particularly in Central Papua and Nabire Regency.

This study aims to analyze the spatio-temporal pattern of recorded TB cases in Nabire Regency from 2023 to 2025 using GIS and to identify priority areas for program monitoring. The contribution of this study lies in transforming routine health data from official publications into operational spatial-temporal information, including TB case rates per 100,000 population, annual choropleth maps, inter-annual changes, and district-level priority classifications.

LITERATURE REVIEW

Tuberculosis surveillance is essential for monitoring case detection, treatment continuity, and program performance. At the local level, tuberculosis data are often presented as aggregate tables by administrative area. Although these data are useful for routine reporting, they do not directly reveal spatial inequality, temporal change, or priority areas. Therefore, population-based indicators and area-based analysis are needed to support more proportional comparisons between districts (Organization, 2025), (Indonesia, 2025).

Recorded tuberculosis cases should be interpreted carefully because they may be influenced by population size, diagnostic access, case-finding intensity, reporting quality, and health-service availability. Districts with large populations may report high absolute case counts, while smaller districts may show a higher relative burden after standardization by population. For this reason, case rates per 100,000 population provide a more proportional measure, although they still represent recorded cases rather than all tuberculosis events occurring in the community.

A Geographic Information System (GIS) supports the integration of health attributes with geographic data for spatial analysis, visualization, and location-based decision making. In disease mapping, GIS can be used for data cleaning, attribute standardization, spatial joins, indicator calculation, choropleth mapping, and temporal comparison (Orozco-Acosta et al., 2023) emphasized that spatio-temporal disease mapping must consider data structure, spatial dependence, temporal variation, and software implementation.

Previous international studies have applied GIS and spatio-temporal methods to examine tuberculosis distribution. Analyzed tuberculosis distribution and seasonality in Shanghai, (Shartova et al., 2023) examined spatial patterns in relation to social determinants in Russia investigated the spatio-temporal epidemiology of tuberculosis in Thailand, and similar studies were conducted in South Korea, Zimbabwe, Malaysia, and mainland China (Im & Kim, 2021), (Gwitira et al., 2021), (Mohidem et al., 2021). These studies consistently showed that tuberculosis is geographically uneven and may persist in particular locations over time.

In Indonesia, spatial tuberculosis studies have been conducted in West Java, Malang Raya, Surakarta, DKI Jakarta, Bekasi, Makassar, Aceh, Padang, Kupang, and Semarang (Madao et al., 2024), (Olivionita et al., 2024), (Nahak et al., 2024). These studies used approaches such as choropleth mapping, spatial diffusion analysis, hotspot detection, and risk-factor modeling. Their findings indicate that tuberculosis burden is often concentrated in specific administrative areas and may be influenced by population density, service access, reporting patterns, and socioeconomic conditions.

However, many previous studies focused on a single year, explanatory risk factors, hotspot identification, or drug-resistant tuberculosis. Fewer studies have transformed routinely published district-level data into a multi-year operational priority classification that combines absolute case counts, population-standardized rates, and inter-annual changes. Evidence from Central Papua, particularly Nabire Regency, also remains limited (Hasriyati et al., 2026).

This study addresses these gaps by analyzing recorded tuberculosis cases in Nabire Regency from 2023 to 2025 using district-level routine data. The study integrates case counts, population denominators, administrative spatial data, annual choropleth maps, inter-annual changes, and priority area classification. The framework is intended as an operational decision-support approach for identifying districts that require intensive monitoring, program strengthening, continued surveillance, or reporting verification.

METHOD

This study employed a descriptive quantitative approach based on a Geographic Information System (GIS) to analyze the spatio-temporal distribution of recorded tuberculosis cases in Nabire Regency from 2023 to 2025. The study focused on describing the distribution of recorded cases, population-standardized case rates, inter-annual changes, and district-level priority areas. It did not examine causal relationships among epidemiological or socioeconomic variables. GIS was used to integrate health attribute data with district administrative spatial data and to transform routine tabular records into spatial information for area-based tuberculosis program monitoring.

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The study was conducted in Nabire Regency, Central Papua Province, Indonesia. The units of analysis were the 15 administrative districts because tuberculosis case data and population data were available at the district level. The observation period covered recorded tuberculosis cases in 2023, 2024, and 2025.

The study used secondary data obtained from official publications of Statistics Indonesia of Nabire Regency and the Nabire Health Office. Recorded tuberculosis case data for 2023 were obtained from Nabire Regency in Figures 2024, data for 2024 from Nabire Regency in Figures 2025, and data for 2025 from Nabire Regency in Figures 2026 (Nabire, 2024), (Nabire, 2025), (Nabire, 2025). Population data were used as denominators for calculating case rates, whereas district administrative boundaries were used as the spatial layer. Spatial data processing, attribute integration, classification, and map preparation were conducted using QGIS (QGIS.org, 2026). The data sources and research variables are presented in Table 1.

Table 1. Data Sources and Research Variables

Data or Variable	**Period**	**Source**	**Unit or Definition**	**Analytical Function**
Recorded tuberculosis cases	2023	Nabire Regency in Figures 2024 and Nabire Health Office	Number of tuberculosis cases reported by district	Measures the absolute recorded case burden
Recorded tuberculosis cases	2024	Nabire Regency in Figures 2025 and Nabire Health Office	Number of tuberculosis cases reported by district	Measures the absolute recorded case burden
Recorded tuberculosis cases	2025	Nabire Regency in Figures 2026 and Nabire Health Office	Number of tuberculosis cases reported by district	Measures the absolute recorded case burden
District population	2023–2025	Statistics Indonesia of Nabire Regency	Number of residents in each district and year	Denominator for calculating case rates
District administrative boundaries	According to layer metadata	Administrative spatial-data source	Polygon boundaries of the 15 districts	Spatial layer for attribute joins and mapping
Tuberculosis case rate	2023–2025	Calculated by the authors	Recorded cases per 100,000 population	Supports proportional comparison among districts
Inter-annual change	2023–2025	Calculated by the authors	Difference between consecutive annual values	Identifies increasing, decreasing, and fluctuating patterns
Priority category	2023–2025	Classified by the authors	Main, strengthening, monitoring, or low priority	Identifies operational priority areas
GIS processing software	2026	QGIS [6]	Spatial-data processing application	Supports attribute joins, classification, and map production

Absolute case counts may produce biased comparisons among districts with different population sizes. Therefore, recorded tuberculosis case rates were calculated per 100,000 population using Equation (1).

$$TBCR = \frac{RTBC}{POP} \times 100{,}000 \qquad (1)$$

Where $TBCR$represents the recorded tuberculosis case rate per 100,000 population, $RTBC$represents the number of recorded tuberculosis cases in a district, and POPrepresents the population of the corresponding district and year. The calculation was conducted separately for each district in 2023, 2024, and 2025.

Data processing was conducted chronologically through data collection, data cleaning, district-name standardization, population matching, case-rate calculation, data validation, attribute-spatial integration, choropleth mapping, inter-annual change analysis, and priority-area classification. District names in the tuberculosis, population, and spatial datasets were standardized before the attribute join to prevent unmatched records caused by differences in spelling or naming conventions.

Data validation was performed before spatial analysis. The sum of district-level tuberculosis cases was compared with the officially reported regency total for each year. Missing values, duplicated district records, inconsistent data formats, and unmatched district names were checked manually. After the attribute join, the number of successfully matched spatial records was compared with the 15 districts included in the original tabular data. The case-rate calculations were also reviewed to ensure that each recorded case value was divided by the population of the corresponding district and year.

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The overall research workflow is illustrated in Figure 1.

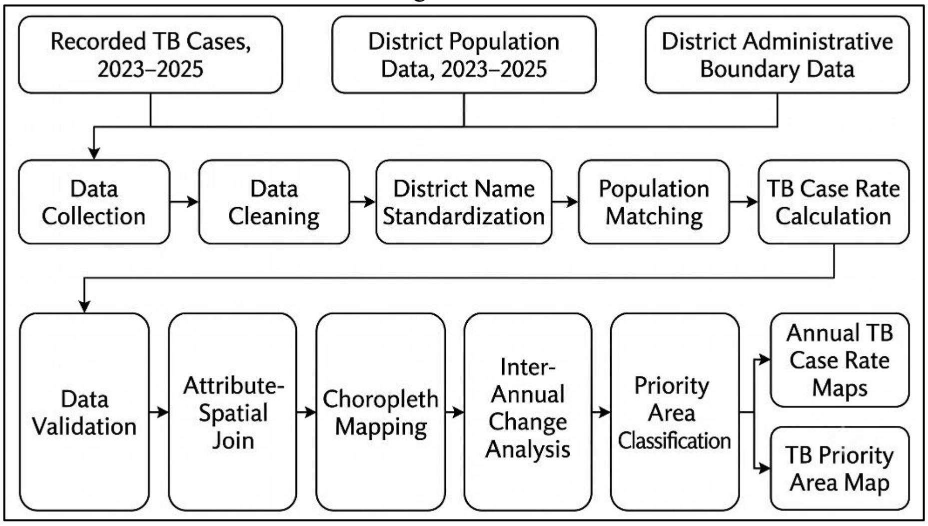

Figure 1. Research Data Processing Workflow

Annual choropleth maps were produced to visualize variations in recorded tuberculosis case rates among districts. Districts with zero recorded cases were presented separately from districts with recorded cases. Districts with non-zero values were grouped into low, moderate, high, and very high categories according to the classification applied consistently during map preparation. The same classification procedure was maintained for the annual maps to support comparison across 2023, 2024, and 2025.

Inter-annual changes were calculated for the periods 2023–2024 and 2024–2025. Positive values indicated an increase, whereas negative values indicated a decrease. The interpretation considered both absolute recorded cases and rates per 100,000 population because districts with relatively small populations could show high rates despite having fewer absolute cases.

Priority-area classification was determined by considering the consistency of annual case rates, absolute recorded case burden, and the direction of inter-annual change. The operational criteria are presented in Table 2.

Table 2. Priority Area Classification Criteria

Criteria	Priority Status	Operational Interpretation
High or very high case rates during at least two observation years, or a consistently high absolute case burden combined with a high population-standardized rate	Main priority	Requires intensive monitoring, strengthened case finding, reporting evaluation, and service review
A high rate in one observation year followed by a renewed increase in the latest year	Strengthening priority	Requires strengthened monitoring, data verification, and program evaluation
Moderate, newly emerging, or fluctuating recorded cases without persistent high rates	Monitoring priority	Requires continued surveillance and validation of reporting trends
No recorded cases or consistently very low recorded case rates during most of the observation period	Low priority	Not an initial intervention focus, but reporting and case-detection performance should remain monitored

The final outputs consisted of annual recorded-case summaries, tuberculosis case rates per 100,000 population, inter-annual change tables, annual choropleth maps, and a tuberculosis priority-area map. The classification was developed as an operational priority-mapping approach rather than a final epidemiological risk model. Therefore, the results were interpreted as supporting information for program monitoring, data verification, and district-level decision making.

RESULT

Recorded tuberculosis cases in Nabire Regency changed substantially during the 2023–2025 observation period. A total of 2,142 cases were recorded in 2023. This number increased to 3,084 cases in 2024 and then decreased to 2,371 cases in 2025. The increase from 2023 to 2024 was 942 cases or 43.98%, whereas the decrease from 2024 to 2025 was 713 cases or 23.12%. The annual trend is presented in Table 3 and Figure 2.

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Table 3. Annual Trend of Recorded Tuberculosis Cases in Nabire Regency, 2023–2025

Year	Recorded TB Cases	Change from Previous Year	Percentage Change
2023	2,142	–	–
2024	3,084	+942	+43.98%
2025	2,371	−713	−23.12%

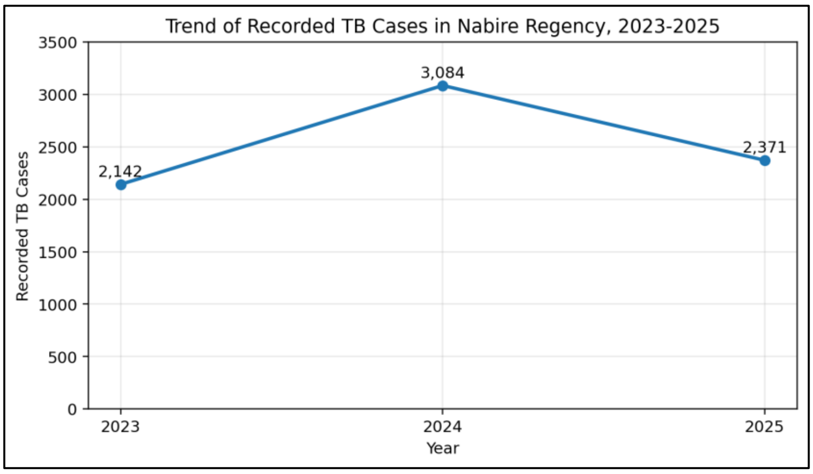

Figure 2. Trend of Recorded Tuberculosis Cases in Nabire Regency, 2023–2025

The district-level distribution showed that recorded tuberculosis cases were not evenly distributed across Nabire Regency. Nabire District consistently recorded the highest absolute number of cases, with 1,821 cases in 2023, 2,174 cases in 2024, and 1,956 cases in 2025. Nabire Barat, Wanggar, Teluk Kimi, and Uwapa also showed notable case counts during the observation period.

Table 4. Recorded Tuberculosis Cases by District in Nabire Regency, 2023–2025

District	2023	2024	2025	Observed Pattern
Uwapa	32	8	25	Decreased, then increased
Menou	0	0	2	Appeared in 2025
Dipa	0	0	0	No recorded cases
Yaur	3	3	8	Increased in 2025
Teluk Umar	0	0	4	Appeared in 2025
Wanggar	76	84	61	High, then decreased
Nabire Barat	102	752	194	Sharp increase, then decreased
Nabire	1,821	2,174	1,956	Consistently highest
Teluk Kimi	68	30	78	Fluctuated and increased in 2025
Napan	3	0	3	Low fluctuation
Makimi	17	3	20	Decreased, then increased
Wapoga	0	1	0	Very low fluctuation
Kepulauan Moora	0	10	1	Appeared in 2024, then decreased
Siriwo	3	9	8	Increased and remained relatively stable
Yaro	17	10	11	Relatively stable
Nabire Regency	2,142	3,084	2,371	Increased in 2024, then decreased

Recorded tuberculosis case rates were calculated per 100,000 population to provide a proportional comparison among districts. Nabire District recorded rates of 1,749.50 per 100,000 population in 2023, 2,099.85 in 2024, and 1,883.32 in 2025. Wanggar also showed consistently high rates, reaching 1,167.26 in 2023, 1,436.14 in 2024, and 988.65 in 2025. Nabire Barat recorded the highest annual rate in 2024 at 4,580.62 per 100,000 population before decreasing to 1,169.45 in 2025.

Table 5. Tuberculosis Case Rates and Inter-Annual Changes by District, 2023–2025

District	Rate 2023	Rate 2024	Change 2023–2024	Rate 2025	Change 2024–2025
Uwapa	773.69	203.46	−570.23	647.67	+444.21
Menou	0.00	0.00	0.00	213.68	+213.68
Dipa	0.00	0.00	0.00	0.00	0.00
Yaur	105.60	98.68	−6.92	246.23	+147.55
Teluk Umar	0.00	0.00	0.00	293.26	+293.26

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Wanggar	1,167.26	1,436.14	+268.88	988.65	−447.49
Nabire Barat	643.78	4,580.62	+3,936.84	1,169.45	−3,411.17
Nabire	1,749.50	2,099.85	+350.35	1,883.32	−216.53
Teluk Kimi	384.18	163.48	−220.70	414.21	+250.73
Napan	183.60	0.00	−183.60	171.14	+171.14
Makimi	217.11	37.33	−179.78	244.38	+207.05
Wapoga	0.00	93.90	+93.90	0.00	−93.90
Kepulauan Moora	0.00	546.75	+546.75	55.28	−491.47
Siriwo	114.85	390.96	+276.11	341.59	−49.37
Yaro	341.02	113.07	−227.95	119.75	+6.68
Nabire Regency	1,228.02	1,732.53	+504.51	1,315.83	−416.70

The five districts with the highest recorded tuberculosis case rates in 2025 were Nabire, Nabire Barat, Wanggar, Uwapa, and Teluk Kimi. Their respective rates were 1,883.32, 1,169.45, 988.65, 647.67, and 414.21 per 100,000 population.

The annual choropleth maps showed changes in the spatial distribution of recorded tuberculosis case rates. In 2023, relatively high rates were observed in Nabire, Wanggar, Uwapa, and Nabire Barat. In 2024, Nabire Barat recorded the highest rate, while Nabire and Wanggar remained in the high-rate group. In 2025, Nabire, Nabire Barat, and Wanggar continued to show high relative burdens, while Uwapa and Teluk Kimi showed renewed increases.

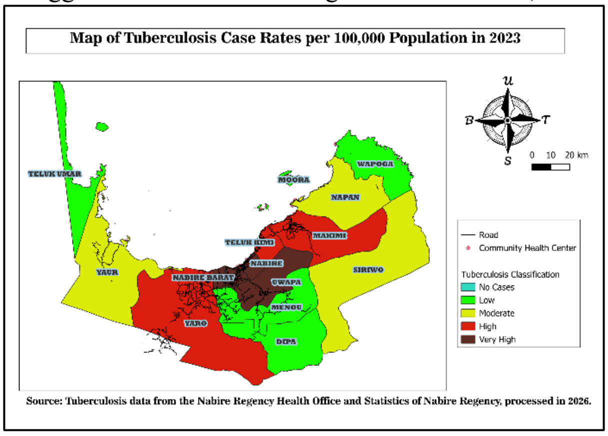

Figure 3. Spatial Distribution of Recorded Tuberculosis Case Rates in Nabire Regency, 2023

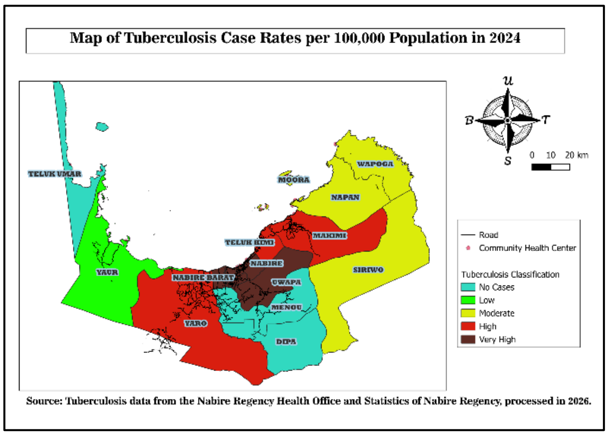

Figure 4. Spatial Distribution of Recorded Tuberculosis Case Rates in Nabire Regency, 2024

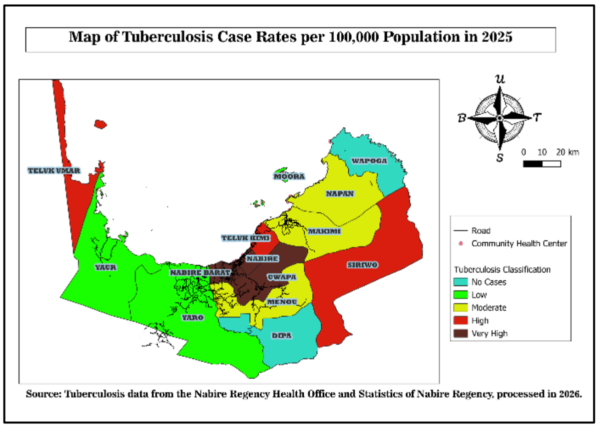

Figure 5. Spatial Distribution of Recorded Tuberculosis Case Rates in Nabire Regency, 2025

Priority-area classification was determined from the consistency of annual rates, absolute case burden, and inter-annual changes. Nabire, Nabire Barat, and Wanggar were classified as main-priority areas. Uwapa and Teluk Kimi were classified as strengthening-priority areas because they showed renewed increases in 2025. Siriwo, Makimi, Yaur, Teluk Umar, Menou, Napan, Yaro, and Kepulauan Moora were classified as monitoring-priority areas. Dipa and Wapoga were classified as low-priority areas.

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Table 6. Tuberculosis Priority Area Classification in Nabire Regency

Priority Status	District	Basis for Classification	Operational Meaning
Main priority	Nabire	Highest absolute case burden and consistently very high rates	Intensive monitoring, strengthened case finding, and service evaluation
Main priority	Nabire Barat	Very high rate in 2024 and remained high in 2025	Evaluation of the 2024 surge and continued monitoring
Main priority	Wanggar	High rates during the three-year period	Intensive monitoring and program verification
Strengthening priority	Uwapa	High rate in 2023 and renewed increase in 2025	Strengthened monitoring and data verification
Strengthening priority	Teluk Kimi	Fluctuating pattern and renewed increase in 2025	Strengthened monitoring and program evaluation
Monitoring priority	Siriwo, Makimi, Yaur, Teluk Umar, Menou, Napan, Yaro, and Kepulauan Moora	Recorded, emerging, or fluctuating cases	Continued surveillance and reporting validation
Low priority	Dipa and Wapoga	No recorded cases or consistently very low values	Continued monitoring of reporting and case detection

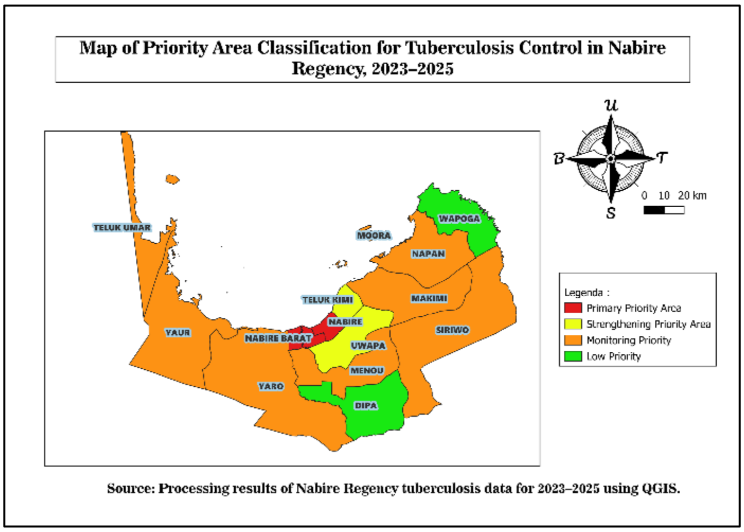

Figure 6. Tuberculosis Priority Areas in Nabire Regency, 2023–2025

DISCUSSION

The findings show that recorded tuberculosis cases in Nabire Regency changed substantially during 2023–2025. Cases increased from 2,142 in 2023 to 3,084 in 2024 and then decreased to 2,371 in 2025. These changes should be interpreted as variations in recorded tuberculosis burden rather than direct evidence of changes in true disease incidence because recorded cases may be influenced by screening intensity, diagnostic access, reporting quality, service utilization, and case-finding capacity.

Nabire District consistently recorded the highest absolute number of cases during the observation period. This pattern is reasonable because Nabire is the main urban and service center of the regency and has a larger population than many other districts. However, after the data were standardized using population denominators, Nabire Barat and Wanggar also showed high relative burdens. This result confirms that absolute case counts alone are insufficient for identifying priority areas because districts with smaller populations may record fewer cases but still have higher rates per 100,000 population.

Nabire Barat showed a very high rate in 2024 and remained relatively high in 2025, while Wanggar maintained high rates throughout the three-year period. These patterns justify the classification of Nabire, Nabire Barat, and Wanggar as main-priority areas. Their classification reflects the combination of absolute case burden, population-standardized rates, and temporal consistency rather than dependence on a single indicator.

Uwapa and Teluk Kimi showed decreases in 2024 followed by renewed increases in 2025. These patterns demonstrate the importance of multi-year analysis because a single-year observation may not capture fluctuations in recorded burden. Therefore, both districts were classified as strengthening-priority areas. This classification indicates the need for strengthened monitoring and data verification without immediately interpreting the increase as evidence of

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sustained transmission.

Districts with zero or very low recorded cases also require careful interpretation. Dipa recorded no cases during the study period, while Wapoga recorded only one case in 2024. Such values do not necessarily indicate the absence of tuberculosis because they may reflect limited screening, restricted access to diagnostic services, incomplete reporting, or cases being recorded in another service area. Therefore, low-priority classification should not be interpreted as a reason to discontinue surveillance.

The spatial patterns identified in this study are consistent with previous research showing that tuberculosis burden is geographically uneven and often concentrated in specific administrative areas. Studies in Indonesia have also demonstrated the usefulness of GIS for identifying high-burden areas, spatial inequalities, and differences related to population density, access to services, and reporting patterns . The present study extends this evidence by integrating three consecutive years of routine district-level data, population-standardized rates, inter-annual changes, and operational priority classification.

The main contribution of this study to Informatics lies in transforming routine health data into structured spatio-temporal information. The analytical process included data cleaning, district-name standardization, population matching, rate calculation, data validation, attribute-spatial integration, choropleth mapping, temporal comparison, and priority-area classification. These stages demonstrate that GIS can function not only as a visualization tool but also as a computational decision-support approach for area-based health monitoring.

From a practical perspective, Nabire, Nabire Barat, and Wanggar require more intensive monitoring, including strengthened case finding, evaluation of reporting completeness, review of diagnostic access, and monitoring of treatment continuity. Uwapa and Teluk Kimi require strengthened surveillance because of renewed increases in 2025. Other districts should remain under routine monitoring, particularly those with emerging or fluctuating recorded cases.

This study has several limitations. The data represent recorded or reported tuberculosis cases and do not capture all tuberculosis events occurring in the community. The analysis was conducted at the district level and may therefore conceal variation at the village, household, or individual level. Temporal comparisons may also be affected by changes in screening, reporting practices, and service access. In addition, the priority classification depends on the quality of case data, population denominators, and the selected classification procedure. Therefore, the resulting priority map should be interpreted as an operational monitoring tool rather than a final epidemiological risk model.

CONCLUSION

This study demonstrates that a Geographic Information System can be used to analyze the spatio-temporal distribution of recorded tuberculosis cases in Nabire Regency from 2023 to 2025. Recorded cases increased from 2,142 in 2023 to 3,084 in 2024 and then decreased to 2,371 in 2025. The distribution was not uniform across districts. Nabire consistently recorded the highest absolute number of cases, while Nabire Barat and Wanggar also showed high relative burdens after case counts were standardized per 100,000 population.

Based on the combination of absolute case burden, population-standardized rates, and inter-annual changes, Nabire, Nabire Barat, and Wanggar were identified as main-priority areas. Uwapa and Teluk Kimi were classified as strengthening-priority areas because they showed renewed increases in 2025. The main contribution of this study lies in transforming routine health data into operational spatio-temporal information through data cleaning, validation, attribute-spatial integration, choropleth mapping, temporal comparison, and priority-area classification.

The results can support district-level tuberculosis program monitoring, reporting evaluation, case-finding strategies, and service planning. However, the findings should be interpreted as an operational monitoring tool rather than a final epidemiological risk model because the analysis used recorded cases and district-level aggregated data. Future research should use more detailed village-level or case-coordinate data and incorporate variables such as health-service access, population density, socioeconomic conditions, treatment history, and relevant comorbidities.

RECOMMENDATIONS

The Nabire Health Office should prioritize Nabire, Nabire Barat, and Wanggar for intensive tuberculosis monitoring, while Uwapa and Teluk Kimi require strengthened surveillance and data verification. Future studies should use more detailed village-level or case-coordinate data and include health-service access, population density, socioeconomic conditions, treatment history, and relevant comorbidities to improve spatial analysis and priority identification.

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